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MISSION AND SPACECRAFT SUPPORT FUNCTIONS OF THE MATERIALS ENGINEERING BRANCH

A SPACE ORIENTED TECHNOLOGY RESOURCE

AARON FISHER
CHARLES L. STAUGAITIS

MAY 1974

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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Materials Engineering Branch

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PREFACE

The prime intent of this document is to indicate to the new members of the Goddard technical and managerial community that a viable, diversified, technical resource exists at GSFC to provide quick solutions to their spacecraft and associated problems. The format develops the many various types of assistance given specific spacecraft systems over a period of more than ten years.

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MISSION AND SPACECRAFT SUPPORT FUNCTIONS
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INTRODUCTION

The Materials Engineering Branch is an experienced "quick response" Goddard resource specializing in problems of material analyses, technology, and processing, as they impact unit flight systems and spacecraft. Its capabilities encompass broad areas of diverse technology as indicated by the following.

- (a) The Branch significantly advanced the state of the art in developing the rigid, digitated "interlocking seam" gravity-gradient booms and corresponding deployment mechanism. Such extendable booms with their improved strength and rigidity provided the spin deceleration necessary to correct Nimbus-D tumbling when its momentum wheel failed and the attitude control system became unstable.
- (b) Development of a patented, flight tested, in-house process for R.F. shielding of the exposed-cable/connector-interface has led to its use with a large number of connectors on the IMP-H, I, J series. The process is presently specified by project management for the Sun Explorer series and has provided a greatly improved spacecraft reliability. ATS-F is flying experiments such as the "Advanced Thermal Flight Experiment," . . . "Quartz Crystal Microbalance Contamination Monitor Experiment," . . . "The Millimeter Wave Experiment Modulator Amplifier and Comsat Propagation Experiment," which have been similarly RF protected. Overall program summary in relation to specific areas of use is detailed more fully later under IMP-H.
- (c) The modus operandi of Nimbus radiant cooler failures, due to contaminants, and our expertise in the field, has led the Branch to invent instrumentation, especially adapted to analyze the effect of angstrom thick contaminant films on "cooler" degradation. A modified film thickness analyzer has been submitted as experiment hardware, suitable for flight on the "Shuttle Applications Facility." The instrument will investigate spacecraft contamination, while in orbit.
- (d) The Branch developed an anhydrous, liquid ammonia-resistant, ethylene propylene rubber for valve seats and "O" rings in the auxiliary station-keeping propulsion system of ATS-E. This material's ammonia

resistance far exceeded that of neoprene, normally used for short term application and was the first instance of such adaptation to this very hostile chemical environment. It has been highly successful. On command exercising, after three years in space, the auxiliary propulsion system, still functional, demonstrated neither "O" ring nor valve seat pressure leaks.

- (e) Although the Branch has demonstrated many important assists and developments, its successful test floating of the 13-story ECHO-II with heated air, valved at predetermined air input rates has been a career highlight. This effort began with laboratory analysis of the biaxial strain rate failure mechanism of ECHO skin gores, included microscopic defect studies on gores and their failure modes, inspection of on-line high speed skin manufacture, and culminated with a precise photogrammetric strain measurement test across the face of the inflated structure. Ultimate data analysis led to resolution of prior, premature inflation failures, guided later ECHO construction specifications, and permitted the prediction of successful performance in the subsequent December 1965 Static Inflation Test conducted at the Lakehurst Naval Air Station in New Jersey.

The Branch, comprised of 20 professionals and 7 technicians, is designed to be interdisciplinary in its technology expertise and encompasses the primary fields of polymers, metallurgy, and ceramics relative to physical properties and applications. Such a technology integration, with appropriate instrumentation, allows quick analysis of all aspects of a problem material system with quick decision implementation, or can provide a firm base for solving spacecraft problems of intermediate term duration.

The foregoing is a broad treatment of our laboratory and extracurricular scientific capabilities. The Branch, in addition to its in-house problem solving operations, provides a functional "reach-out" service concept. It has assigned specific, experienced, professional, "material problem solving" liaison staff to each of Goddard's flight spacecraft projects since 1962. Project Managers and technical officers involve the liaison specialist both as the materials technologist for their spacecraft, and as their go-between towards the enlistment of the Branch's broad technical talents for any materials problem solution. The liaison specialist is always "on call," and wholly responsive to the project's material technology needs. He attends project meetings, becomes immersed in the various system technologies, discusses anticipated problems or recommends new materials. In many instances, he provides an explanatory know-how of a vendor's material process to the technical officer when an uncooperating vendor may indicate that such process is proprietary. In other situations, he assists the technical officer to solve a vendor's problem through direct verbal communication, and helps keep schedules on time. At other times, problem hardware

may be brought directly in-house from the vendor, and extensive work testing or analysis performed on it, before arriving at a final problem solution. Many times, the liaison may require the services of other MEB specialists to solve problems cross country, at the vendor's establishment. In one instance, the liaison to AE developed processes for, and personally fabricated six sets of thermal louvers "in-house," as backup, when the vendor's original design failed and it appeared as though he could not meet his schedule commitment. The liaison professional reaches out for existing or anticipated spacecraft problems bringing the more difficult ones back to the laboratory. Here, the various discipline specialists, including possibly himself, can, with appropriate instrumentation, focus their capabilities on the matter, in-concert, thereby maximizing the possibilities for rapid problem solution.

The in-depth liaison specialist has one additional potent tool. He has access to a computerized retrieval system for a memo data bank comprising 2200 technical problem solving memos issued by the Branch over the last eight years, each with up to five different "apropos" subject matter items, selected from an infinite number of possible topics. For example, he can easily select memos on all of Goddard's spacecraft lubrication problems for special study or only those pertaining to OAO or Nimbus. And, similarly, this resource is available in the problem areas of contamination, solar cells, paints, coatings, on 'ad-infinity.'

In addition to being a resource that acts quickly on "now" problems, the Branch is also a resource for anticipating and preventing future problems. In this regard, the Branch is Goddard's sole guide and referee relative to material types allowed in spacecraft. Providing of material lists to the MEB for review is now compulsory and officially incumbent on all potential Goddard spacecraft vendors, prior to any design phase review. Special forms have been originated for this material listing. This early initial review eliminates many potential problem materials at the beginning of a program and minimizes future extra costly rework. The Branch staff has authored and widely disseminated a total of 95 NASA-TNs, X-Documents, Materials Technology Reports, Articles, and Technical Symposium papers on specific areas of technology related to spacecraft. Twelve patents have been awarded. Three are in process. A bibliography and patent list are appended to the Activity Report.

Individual staff members are always present at, or contribute to, the innumerable spacecraft readiness review meetings held by the LaGow-Moseson Systems Reliability Directorate.

The Branch has, in dire emergency situations, assisted other NASA centers, viz., Marshall Space Flight Center, when urgent test and analytical input were required by them soon after launch, re., the future integrity of two complex laminated fabrics used as thermal shield materials on SKYLAB. The Engineering

Applications Branch joined in this effort. It was the cooling capability as provided by this type blanket, and subsequently applied by the Astronauts, which enabled Skylab to continue operationally and successfully to the completion of its assigned mission.

The Branch is a multifaceted resource. It provides total technological capabilities to Goddard spacecraft programs at all times and, thereafter, to other centers and their cognizant spacecraft, when required. It developed the manufacturing know how for the gravity gradient stabilized boom experiment on ATS-E. These same type 150 foot extendable and retractable booms have been employed by the Navy in a new series of operational satellites. One staff member has written a chapter on "booms" in Aerospace Mechanisms, Vol. 1, May 1969.

The Branch is also strong on the international scene, providing continual materials support to the Canadian satellites ISIS, CTS, . . . Germany's Helios, . . . IUE, ANS, AEROS, and other craft of the ESRO community. The Branch's entire outgassing contamination study facility has been rebuilt on the continent by ESRO with our assistance. We are involved in international round robin contamination studies. The Branch has even provided the material analysis for the Surveyor III television cable, previously left on the moon, and subsequently retrieved.

The scope and importance of these capabilities are specifically shown in the Branch's spacecraft activity report as enclosed below.

ACTIVITY REPORT

ACTIVITY REPORT

The Materials Engineer carries out a variety of equally important satellite support functions as noted below:

1. Materials review
2. Material and processing information dissemination
3. Laboratory support capability

Spacecraft Materials Review Function

- (a) Spacecraft materials list review and recommendations where necessary
- (b) Quality test plans and test report reviews
- (c) Contractor material processing and failure analysis review
- (d) Guidance of lab testing (in-house)
- (e) Test consultation and evaluation
- (f) Attendance and recommendations at Design and Flight Readiness Reviews
- (g) TAC participation in support of SEB actions.

Materials and Processing Information Dissemination

Mention must be made of the important effort aimed at significantly reducing the incidence of material problems arising from the vendor's technical failings or his lack of awareness for material processing subtleties which can prove hazardous to spacecraft or experiments. This MEB program currently in effect includes:

- (a) "Materials Information Request Form" attached to all future PR's
- (b) Dissemination of Outgassing Reports, as an anti-contamination service
- (c) Material Alert submissions
- (d) Continual upgrading of the MEB technical memoranda bank resource to expedite data surveys

- (e) Periodic release of "easy reading" Materials Technology Reports (aimed at the Hardware Design Engineer)
- (f) Publication of a Materials Guide.

Laboratory Support Capability

No attempt has been made to discuss in detail, the variety of laboratory facilities and testing instruments currently used on a routine basis to solve the numerous material problems submitted. However, some of the more important laboratory support functions rendered to the Center's Projects on a continuing basis include.

- (a) Metallographic and fractographic analysis
- (b) Mechanical testing (fatigue, stress-rupture, static tension/compression, etc.)
- (c) Physical measurements analysis (optical, thermal conductivity, thermal expansion, etc.)
- (d) Thermal measurements analysis (accelerated temperature/strain rate loading, thermal bending of boom structures, etc.)
- (e) VCM* (outgassing characteristics)
- (f) Chemical analysis (rapid computerized mass spectrometry, gas chromatography, gel permeation, emission, atomic absorptance, etc.)
- (g) Nondestructive testing (NDT) - dye penetration, radiography, stress-coating)
- (h) Polymeric services (potting/encapsulation, devolatizing resins, special paint development, material and process selection, anti-contamination program, battery separator program for improved long term properties
- (i) Metal processing and surface modification (heat treatment, peen plating, etc.)
- (j) Joining (ruby laser, spot welding, adhesives, etc.)

*Volatile Condensable Materials

- (k) Bearing/lubrication facility (complete processing and inspection of flight bearings).

Finally, in support of the Summer Institute for Biomedical Engineering under the auspices of the Technology Utilization Office, the MEB provided the technical advisors relative to the two study activities noted.

- (1) Design Modification of Electrophoretic Equipment
- (2) Operating Room Environment Control.

The foregoing represent the general type of materials support provided to the Center's satellite projects, launch vehicles and experiments. The specific problems and direct assists described below are considered typical of the kind of laboratory support requests received, and are included to demonstrate the technical diversity, capability and service which the projects have come to expect of the MEB.

CASE HISTORIES
OF
LABORATORY SATELLITE SUPPORT

CASE HISTORIES OF LABORATORY SATELLITE SUPPORT

ATS-F

Problem of Heat Pipe Porosity and Embrittlement

In the course of producing flight heat pipes, the vendor was plagued with a variety of processing and fabrication problems. A major problem was inadvertently discovered during a routine inspection of a sealed C-pipe, damaged during machining, and rejected for flight use. Detailed examination showed much grey-white residue which could easily be scraped off, revealing a porous, black underlying surface. In addition, the fins were so embrittled that segments fell off during sectioning of the pipe. Since the thermal control of the ATS-F satellite depends primarily on the efficient operation of some fifty-five internally grooved aluminum heat pipes, the significance of this materials problem was self-evident. A full scale investigation was undertaken. Results of metallographic, chemical analysis, and mechanical tests established that residual water subjected to high temperature ($\approx 1000^{\circ}\text{F}$) during vendor heat treatment was primarily responsible for the combined porous black oxide surface. This condition drastically reduced the aluminum's compressive strength level. Extended vacuum pumpdown time and temperature were shown to be important for removing adsorbed and hydrated water from the pipe's internal surfaces, prior to cap-off and heat treatment. A simplified cleaning process insuring the absence of entrapped moisture was developed. The implementation of the MEB modified fabrication practices and revised cleaning process by the vendor resulted in the complete resolution of this ATS-F materials system problem. The new processing will insure a continued reliability for this efficient mode of thermal control on future spacecraft.

The MEB is currently involved in developing optimized heat pipe manufacturing methods and processes for a variety of materials, fluids, and designs that will ultimately result in a standardized specification for future heat pipe procurement.

Parabolic Reflector

Plating of Dacron Mesh—Funding limitation was the primary reason for replacing the superior gold plated chromel 'R' material, with copper coated Dacron mesh, as the prime candidate for antenna application. This decision, however, stimulated the vendor to develop an improved Dacron mesh having better copper plating adhesion than earlier samples. The adequacy of plating had been a problem in previous mesh materials. The MEB demonstrated that the improved

mesh would survive the expected vibration loads and stresses without "popping" the copper plate. This tighter copper coating was considered able to prolong the service life of the overplated Dacron, normally quite vulnerable to UV degradation. The test program required the design of special holding fixtures and test procedures usually not covered by ASTM test specifications and ultimately established an acceptable confidence level for the material.

Antenna Deployment Failure—The antenna fabric (copper plated Dacron mesh) had been coated with low outgassing DC 6-1104 sealant applied very heavily around the periphery of the antenna and over the seams. During a sub-zero -140°F deployment test, from the tightly spiraled stored condition, the antenna failed to open properly, resulting in torn mesh.

MEB investigation showed that the problem was due to a combination of improper processing and "blocking" (this occurs when some pressed together polymeric materials cannot release upon the removal of pressure).

To prevent the blocking phenomenon from occurring, teflon tape was applied to many of the sections of the antenna (especially around the periphery) where heavy coatings of the DC 6-1104 had been used. The periphery sections especially are under extreme pressure when the antenna is in its spirally twisted, stowed condition. This modification insured that the DC 6-1104 would not be hard pressed against itself in areas where the sealant was thick. All subsequent antenna deployment tests have been successful, a fact which is of primary importance to mission success. Future deployments will not occur below -40°F.

Reflector Rib - Stress Corrosion Evaluation—The flattened curved aluminum rib, support element of the antenna, is subjected to significant levels of combined stressing (tensile and shear), when in the stowed configuration. This condition coupled with the possibility that the 2024 T-6 aluminum rib would be exposed to a mildly corrosive environment posed a potential problem of stress-corrosion cracking (SCC).

Because of this potentially harmful situation, the MEB conducted an in-house investigation to determine, if in fact, long term exposure of a loaded rib in 3% aqueous salt (Na Cl) solution would initiate SCC. The results of these tests demonstrated conclusively, that SCC would pose no problem even after nine months of severe exposure. Since the parabolic reflector will not be stored for longer than six months, and then only in an ambient environment, assurance is indicated that catastrophic failure of the ribs will not occur prior to, during and after launch.

RF-Shielding

The MEB performed potting, encapsulation, conductive cloth wrapping and connector shielding of the following flight hardware:

- (a) GSFC-Quartz Crystal Balance Monitor
- (b) MMW Experiment
- (c) Transmitter and Receiver Units
- (d) Propagation Experiment
- (e) Advanced Thermal Experiment

Effective RF-shielding is necessary to eliminate stray currents, which could result in erroneous interacting signals being received from other experiments. In actual fact, unshielded experiments can be rendered completely ineffectual due to elimination of signal integrity. The above experiments had never been initially programmed for R. F. shielding. The MEB, by developing special conductive adhesives, and utilizing its previously researched and patented procedures, was able to shield these expensive experiments "in house" with little impact on project scheduling.

Evaluation and Development of a Mesh Material for the EVM Shielding Application

When RF shielding requirements for EVM became critical on ATS-F, two candidate mesh materials were considered. Each posed a different problem that had to be resolved before implementation was completely assured.

Gold plated Chromel 'R' was selected for shielding various areas of the Earth Viewing Module (EVM), but the vendor's attempts to locate a local source to gold plate the Chromel 'R' mesh were unsuccessful. However, a superior ductile gold plating process developed jointly by the GSFC Plating Shop and MEB in 1971 for Chromel 'R' specifically, permitted the MEB to coordinate a joint effort, that successfully scaled up the GSFC facility to permit plating the ductile gold on 17 three-foot-square sections of mesh. In addition, the MEB was primarily instrumental in designing the necessary fixtures to properly support the fragile mesh, pointed out precautions to be taken in preparing the mesh for application, and demonstrated through metallurgical examination, that the gold plate exhibited the necessary adherence, ductility, and was of uniform thickness. The gold plated Chromel 'R' supplied to the vendor was subsequently used for R.F. shielding on the Earth Viewing Module, EVM.

EVM - Titanium Screw Stud Failure

During installation of the service module to the experiment module, a titanium (6 Al-4V alloy) stud failed at a torque considerably below specified levels. Metallurgical examination of the fractured stud showed that improper heat treatment and machining practices were responsible for the unexpected failure. This, despite the fact that the vendor called out the correct specification (AMS 7461A) on the design drawings. Specifically, instead of having rolled threads the studs were made with machined threads; instead of being heat treated prior to final machining, heat treating was performed after machining and in air, thereby promoting the formation of a very brittle, oxidized, α -phase metallurgical structure on the surface and root of the threads. Finally, it became evident that metallurgical examinations as specified in AMS 7461A were not even conducted at all by the vendor, since such inspection checks would have revealed the presence of oxide cracking which provided favorable sites for the initiation of and ultimate premature failure.

The steps recommended and since implemented, to eliminate the reoccurrence of this problem consisted of:

- (1) Replacement of all studs presently installed on the spacecraft.
- (2) Random sampling of new acceptable studs to insure their integrity.
- (3) A recommendation to the vendor, that they tighten incoming inspection procedures since the improper condition of the stud's surface could have been detected optically under normal inspection procedures.

Solar Array - Hinge Spring Bracket Failure

During a riveting operation, vendor personnel discovered that a piece of metal had broken off from one of two critical solar array support arms, thus imposing the full torque load on the remaining arm. The failed bracket was so brittle that another piece broke off during disassembly. Presumably, these brackets were manufactured from extruded and machined 2024-T4 aluminum in accordance with specification QQA200/3.

The occurrence of this failure so late in the Project's schedule necessitated emergency action to identify the cause of the problem and render a quick and timely solution. Metallurgical examination by the MEB revealed the presence of an excessively porous microstructure, closely resembling a cast structure, with evidence of extreme overheat as indicated by the existence of incipient

grain boundary melting. The bracket's chemical composition more closely matched the 7072 aluminum alloy rather than the required 2024. Obviously, the vendor had exercised poor incoming inspection practices over critical parts manufactured by the sub-contractor.

Recommended-type replacement brackets were manufactured from rolled plate 2024-T351, submitted for examination and found to be in conformance with specification QQA 250/4 and completely acceptable for flight use. Recommendation for more rigorous inspection procedures and hardness determinations of witness samples to verify heat treat operation, have been submitted and agreed to by the vendor.

Cesium Ion Engine

Investigation of the Premature Failure (burnout) of the Cathode Heaters—The Cesium engine is totally compromised if the cathode heaters do not operate for the required period of time. The MEB's initial metallurgical investigations and complete redesign of these cathode units with improved materials of construction assures that the operational efficiency of this experiment and its chances for success are greatly improved.

Cesium Ion Engine - Exhaust Plume Evaluation—The MEB provided probe examination for the ATS-Cs Ion Engine. In this instance, analysis was performed on specimens deliberately placed at various locations in the exhaust stream. Examination for Cesium on these specimens served to define the profile of the exhaust plume emanating from the engine.

Cesium Ion Engine - Star Tracker Interference Problem—Based on a study by a subcontractor and their own analysis, the primary vendor concluded that the ion engine's exhaust plume would, under excitation of solar radiation, produce additional background illumination thereby seriously degrading Star Tracker performance. The primary vendor proposed a considerable amount of additional analysis and test to investigate this apparent problem. The MEB reviewed both the subcontractor's and the primary vendor's analytical treatments, performed its own analysis, and demonstrated that the contractor was in error by more than two orders of magnitude. Not only were their calculations incorrect, but the vendors also failed to take the Star Tracker's field of view into account. Both of these poorly conceived analytical treatments resulted in the vendor's erroneous conclusion that marked S/N degradation would occur as a result of interference. Fortunately, the correct MEB analysis showed that the background illuminance arising from the Cesium plume was of the same order of magnitude as the star background (1×10^{-13} w/cm²) and thus no S/N degradation would occur. The Project realized significant cost savings from this work.

Resisto Jet Heater Failures

The MEB performed an electron probe analysis on samples of heater wire used in the ATS resisto jet. Analysis helped pinpoint the cause of failures, which was shown to be liquid metal corrosion developed from the braze used in the system. With this information, recommendations were made to change the design and the materials used and these were successfully implemented.

Lubrication

The VHRR and the University of Minnesota experiments are so designed that they could experience early failure if the bearings were improperly lubricated. Since the contractors involved in the experiment fabrications were not knowledgeable in lubrication and poorly equipped to handle bearing problems, the MEB assumed the lubrication inspection responsibility and made necessary recommendations.

The vendor, provided with this information, was successfully able to lubricate the reaction wheel bearings with the MEB's instruction and guidance, thus insuring proper operation of the critical attitude control system.

Evaluation of Adhesive 934 Used to Bond the GFRP (Graphite Fiber Reinforced Polymer) Truss Tubes Into Their Titanium Fittings

Hysol EA 934 adhesive was used to bond the GFRP tubing into titanium socket type end fittings. Since the long, triple-tube truss structure is the prime support for the ATS satellite, a question arose pertaining to the adequacy of these adhesive bonds under various stress conditions.

A long term test program was initiated to evaluate the adhesive at various temperatures and under different loading conditions. Test descriptions follow:

- (1) Tensile impact tests at room temperature and at -10°F
- (2) Creep test conducted for 3100 hours at 315°F
- (3) Tensile tests at various temperatures.

Without adequate bonding capability, the satellite could separate at the titanium fitting joints under various impact configurations experienced during launch and after, thus jeopardizing the entire mission. These tests provided assurances that the adhesive will be more than adequate, especially during the time of reflector deployment, when the tensile impact loading would be at a maximum level.

OA0-A

Sun Baffle

Large black paint particles, potentially capable of dropping into the slits of the Princeton Experiment Package (PEP) and interfering with the optics, were peeling from the very large (PEP) sun baffle provided by the vendor. After successful preliminary laboratory experimentation at GSFC, involving adhesion of a new type flexible coating to the existent brittle one, the MEB decided to overcoat the old with the new flexible type following loose paint particle removal. The total repainting with the new, flexible, low outgassing and well adhering flat black paint insured that no particles could drift into the PEP slit openings. This was confirmed by subjecting the baffle to a vibratory launch sequence which left no particles on the white collecting sheet below it. The baffle is presently flying on the Copernicus spacecraft. OA0-C was also subjected to this refurbishment operation. No problems were experienced. Many thousands of dollars were saved when the need for a new sun baffle was cancelled.

PEP Spectrometer Oil Leak

Oil was leaking from one of the vibration dampers required for the spectrometer. The condensed oil film could potentially interfere with the spectrometer experiment by absorbing light of specific wavelengths, thus causing low estimates of that wavelength in the space environment. After complete chemical analysis of the oil wipings, the MEB determined that only one of four dampers was leaking, and that a system redesign was not necessary, in that only one unit had to be replaced. This was a tremendous backstop support since the clarifying information, non-supportive of the total redesign concept, saved valuable time and money at a very critical period before launch.

OA0-C

Solar Array

Solar Cell Problem—During thermal cycling a significant number of solder joints were failing on the solar cell connections. The solar cell tabs were lifting and causing an "open."

Metallographic examination of both the tab material and solder joints, by MEB, determined that the hardness of the copper tab was greater than desired. In addition, chemical analysis showed some silicone material on the solder area, indicating that poor cleaning was occurring at the manufacturing plant. Thermal

tests determined that remelting by manufacturing personnel would raise the solder melting point and require solder technique changes. The MEB's thorough investigation of these failures brought about many manufacturing process and material changes, which ultimately produced solar cell panels that passed all tests and are presently flying on "Copernicus."

Solar Paddle Squibs—The MEB learned through an ALERT that pyrotechnic squibs, to be used on the solar paddles for deployment were experiencing some manufacturing defects. These defects could be shown by using X-ray radiography to determine the thickness of a specific metal shoulder. If the metal shoulder were too thin, the squib would release improperly and not allow full separation. The MEB took all the squib radiographs on the spacecraft, even the inaccessible ones, with its portable equipment. The MEB demonstrated how the pictures were to be read and how to find and measure the particular shoulder part. Contractor personnel made the measurements.

Results indicated that all squibs were properly manufactured and none had to be replaced. All operated perfectly in space.

Resistor Potting

The polymeric material selected by the manufacturer to encapsulate a hot firing resistor created considerable gas evolution, charring and cracking when the resistor was activated. Specifications required, that the firing release neither contaminant gases nor particles. MEB laboratory tests indicated a better polymer which would neither burn nor char and retained the hot resistor completely.

The manufacturer confirmed our results, and changed over to the MEB selected material. The new resistors flew successfully on "Copernicus."

OSO

Evaluation of Materials

The OSO project realized the importance of obtaining early materials engineering support, and introduced into the OSO-I procurement contract, a requirement for complete materials review and evaluation, prior to both design freezing and inauguration of hardware procurement. In the course of carrying out this task, 3,000 materials and numerous specifications and processes submitted by the prime contractor, its subcontractors, and experiments, were reviewed. This resulted in the preparation of over 80 technical memoranda. As a result of this early review concept, many unsuitable materials intended for spacecraft use were rejected before hardware was fabricated. Recommendations were made

for more reliable, easily available, less costly materials. This review process was an important assist in moving OSO fabrication from conceptualization on through a successful launch without any major problems.

Solar Array

Solar Cell Cover Slip Adhesive Delamination—The OSO array vendors discovered that the cover slips on solar cells, made by a subcontractor, were delaminating. Investigation revealed, that both the adhesive and cleaning procedures used were responsible for this delamination problem. The MEB developed and recommended a revised cleaning procedure and substituted the use of DC 93-500 a new, low outgassing silicone adhesive for bonding the cover slip to the solar cell. Recommendations were accepted and successfully applied by the subcontractor. Arrays having these cells are orbiting successfully, with minimal degradation, on OSO-C.

Solar Array Outgassing Analysis—The OSO-I solar array substrate is made by bonding epoxy fiberglass to aluminum honeycomb. The project assumed that an outgassing problem would arise with this particular system and intended that the solar panel be baked out after fabrication. The MEB had samples of the array run in its VCM facility and determined that the outgassing of this system would not constitute a problem. The elimination of the proposed bake out procedure was recommended and concurred in by the project. Considerable savings resulted.

Radiation Studies

SAA (South Atlantic Anomaly) Problem-OSO-7, OAO-3—During and after passage of the OSO-7 S/C through the SAA (a region of high electron/proton flux) the Star Scanner failed to yield data because its PMT window (Corning 7056 glass) fluoresced, thereby saturating the sensor in the visible range and rendering it inoperative while in this state. A similar phenomenon developed with the UV Princeton Experiment Package (PEP) on Copernicus whereby the MgF_2 -crystal also fluoresced and saturated the counting circuitry as a consequence of electron irradiation. It should be noted, that in this instance the phenomenon persisted for some time (phosphoresced) after the S/C had left this region, thus compounding the 'dark count' problem even more.

At the specific request of Dr. G. Pieper, Director, Space and Earth Science Directorate, the MEB conducted a complex characterization of photomultiplier window materials in terms of fluorescent and phosphorescent emission caused by electron irradiation. This type data for optical windows, in which fluorescence is normally not a considered factor, are not available in the literature. Thus, these results represent the first quantitative data available in this field,

not only for Star Tracker applications but for the design of other low light level experiments.

For OSO-I, the vendor proposed that the OSO-7 type PMT window be replaced with radiation hardened (cesium doped) Schott glass since it was assumed that this particular type glass would fluoresce less. However, the MEB demonstrated experimentally, that this type window fluoresced even more and it was eliminated for this application. A costly mistake and probable experiment failure was avoided. Of the materials examined, high purity fused silica is the only material that does not phosphoresce after particulate irradiation.

This study will have a direct impact on IUE and LST. A NASA TN is being prepared.

Radiation Test on Detector Window Material - OSO-I—The MEB performed electron radiation tests on samples of Schott 8337 glass intended to be used as detector window material for the CNRS (French) experiment on OSO-I. Results of the test showed some degradation due to the radiation exposure especially at the wavelengths of interest (2,700 Å and 2,800 Å). Although the degradation in transmission performance was not considered severe enough to reject it for this particular application, the realization that this material was susceptible to radiation damage enabled the experimenters to take this fact into the overall design considerations in establishing a minimum performance criteria. The MEB also recommended the use of less susceptible materials.

Gas Valves - Fretting Corrosion - U. of Wisconsin Experiment

A Stainless Steel solenoid valve used in the flow proportional counter developed a premature leak of methane gas during life tests. The MEB metallurgical examination showed fretting corrosion. Recommendations for a redesign in harder steel was made. The experiment flew successfully.

Alert - DC 3101 - UV and Visible Spectrometer Experiment (French)

The MEB was asked by the project to evaluate a potting compound which the French intended to use as a vibration damping material. It was discovered that the polymer would not cure as expected and after conducting further tests, it was established that two lots of the material submitted were defective due to processing problems. The OSO project was immediately warned and an ALERT released which conveyed this information to other interested parties as well. A substitute potting compound was recommended to the French experimenter for this purpose, and used successfully.

T&E Test Chambers

Continual pressure by the MEB on spacecraft managers, relative to their use of "dirty" high outgassing test chambers, has prompted them, in turn, to convince chamber operators to make an all-out effort to clean up internal accessories, wiring, and fixtures, before and after each run.

Solder Revision in PPL 12

A significant contribution to the OSO project was the establishment of a change in the soldering procedures outlined in the GSFC PPL11 (Preferred Parts List). The PPL 11 permitted using type RA solder which can be highly corrosive, especially to critical electronic components, while not indicating that Type R (a nonactivated rosin core) solder is perfectly suitable for certain applications. The MEB's recommendation for revision of the soldering specification was accepted by the Quality Assurance Division. The new requirement lists the various acceptable solders in the following order of preference: Type RMA (mildly activated); Type R and Type RA. Also included in the revision to the PPL11 was the requirement for post cleaning of soldered components.

ERTS-A

Reaction Wheel Bearings

Failure of the reaction wheel bearings occurred during qualification testing. This wheel controls the tendency for spacecraft pitching and helps provide a stable platform. The failed bearings were examined by the MEB and recommendations were made to introduce an additive (TCP) to the Mil L 6085 diester oil, the normal bearing lubricant. TCP, tri-cresyl phosphate had been researched in the MEB bearing facility and found to increase bearing life by hundreds of hours. It was added to provide a lubrication interface during low wheel speeds, just prior to change in wheel spinning direction, at which time the Mil L 6085 oil was not able to maintain the hydrodynamic oil film necessary to prevent metal to metal contact. This recommendation was used on the ERTS wheels. The spacecraft orbited and flew successfully with no problems experienced by the reaction wheel system.

Vidicon Tube Electrical Leakage Problem

The MEB provided extensive electron probe support in examining a vendor's RBV Vidicon tubes which exhibited electrical leakage problems. This particular study attempted to determine the extent of barium contamination across the electrode spacers. Results showed conclusively that the electrical leakage occurred

across these spacers as a result of barium contamination (evaporation). This analysis helped describe the problem and brought about a new design which resulted in improved RBV Vidicon tubes.

Multi-Spectral Scanner (MSS) 5th Band Cooler

Fabrication problems with the ERTS 5th band cooler were investigated by the MEB in conjunction with the GSFC technical shops. Procedures for machining the low thermal conductivity Lexan cone support, electroforming the nickel shields and bonding the shields to the cone were successfully developed. These techniques were turned over to the MSS prime contractor to assist in manufacturing the flight model coolers. Units were successfully made, tested and will fly on ERTS-C.

Solar Array Drive Motor

During qualification testing, the solar array drive deployment motors exhibited a noise signal problem characterized by the motor current falling to "0" on occasion. The MEB investigation showed that brush bounce was the principal cause for the motor noise. The MEB recommendation, to purchase a specified improved quality of brush from a different manufacturer, and to lubricate them individually, solved the problem.

Wide Band Tape Recorder Negator Spring Failure

During component level testing of the tape recorder one of the negator springs failed. In space, this would lead to recorder failure and loss of other than real time data. The MEB examined the problem and attributed the failure to a very poor edge condition of the spring, characterized by a multitude of microcracks. A change in manufacturing procedure was recommended and implemented. No further negator spring failures occurred. ERTS-A orbited successfully and passed its six month mission requirement with no recorder failure.

Contamination of the Solar Paddles

Considerable contamination of the solar paddles occurred during component level thermal vacuum (T/V) testing. Contamination can effectively lower the power output of the array, and compromise experiment capability to operate. The MEB recommended the use of low outgassing materials. Thermal cycling tests on simulated array panels utilizing the recommended silicone #566 adhesive indicated they were acceptable.

Future solar arrays manufactured for follow on Nimbus and ERTS spacecraft will be built using the MEB recommended materials.

Contamination Via Protective Film

This problem was unique in that a non-suspect, generally used, protective, strippable polymer film coating, Spray-Lat, was exuding a thin liquid film contaminant. This film was normally not observable, because it was colorless and transparent. A thermal vacuum test of S/C at the vendors brought out the now visible film on the sun sensor and louver surfaces, possibly as a result of UV interaction during test. MEB techniques for contamination cleanup immediately after "Spray-Lat" removal and prior to test was recommended and later implemented by the vendor.

NIMBUS-E

SCMR - Surface Contour Mapping Radiometer

The SCMR failed in orbit on Nimbus-E. MEB staff, invited to a specially convened GSFC investigating committee, recognized after review, that failure was probably caused by a thermal expansion mismatch in the magnetic pick-up unit. A visit to the "pickup" manufacturer, revealed previously unreported large scale failures in their production line units after the thermal cycling. The MEB recommended internal redesign changes incorporating lower thermal expansion, glass filled polymers, and stronger #39 guage instead of the #44 guage copper wire normally used. Modified units were subsequently obtained which passed 50 thermal shock cycles (-55°C to 85°C). A shock cycle consists of a 30-minute period at room temperature before subjecting the sample to an immediate environment of either alternate extreme for a 30-minute dwell. These were exceptionally severe test conditions and non-failure indicated high reliability. The new thermally cycled "pickups" will be used on the AVHRR for TIROS-N and the HCMR, heat capacity mapping radiometer, of the HCMM satellite.

At our request, the manufacturer will continue this modified line as a high reliability magnetic pickup item under specification number 72-44-91 and has frozen all operations used in its production. The ITT number for the same item is 811-83-95.

Low Outgassing White Thermal Control Paints

The MEB developed a white, UV stable, thermal control paint, P-764, for general use on flight hardware. It was applied to the THIR sun shield by the MEB. It is being used on the Nimbus-E ERB experiment and will be applied by the MEB to the expanded memory boxes to be flown on ERTS-B.

NIMBUS-F

Earth Radiation Budget (ERB) Interference Filter Degradation

Earlier tests by the MEB had unexpectedly revealed excessive ultraviolet degradation incurred by two vendor produced, silica substrate, optical film composites (1) silver + cryolite with no overcoat; and (2) aluminum + cryolite with a thorium fluoride overcoat. These units had been intended as interference filters for use in the solar channels of the ERB experiment. Ultraviolet radiation tests, on the fused silica substrate alone, showed at best a modest degradation (2-10% transmission loss). This was insufficient to account for the 40% loss in the 200-400 nm band region, of the complete composite film/silica substrate interference filter system. NOAA disqualified both type filters and made an urgent request to the MEB to save this part of the ERB experiment by recommending films for a new radiation resistant interference filter.

The MEB instituted a literature search and found no information indicating which part of the composite might be susceptible to the UV. The cryolite, common to both filters was postulated as being the degrading film. This was confirmed by direct test. Magnesium fluoride, noted for its radiation resistance to UV, in bulk form, was subsequently tested as a cryolite substitute. It performed well. NOAA requested the vendor to provide new filters substituting the magnesium fluoride, MgF_2 , for the cryolite. The new units passed the radiation criteria, and were flown on the Nimbus-F ERB. The study is being published by the American Ceramic Society.

Degradation of the ERB Filters

The MEB determined the transmission characteristics of the ERB filters after exposure to solar irradiation of up to 1100 equivalent solar hours. It was determined that during initial exposure of the ERB filter to solar irradiation, a small loss in transmission occurred. This loss soon plateaued to where further exposure caused insignificant changes.

Lubrication Problems

As in Nimbus-E, the MEB actively participated in designing lubricant systems for the Nimbus-F experiments. Bearings for the HIRS and LRIR experiments were lubricated in-house. A serious ERB problem in which the harmonic drive failed after only three months of simulated life testing was solved by an MEB recommended lubrication change from G-300 grease to Krytox 240 AC. Harmonic drives lubricated with Krytox grease have survived one year simulated life testing at MEB in vacuum with very minor wear observed.

Vertical Temperature Profile Radiometer - VTPR

Outgassing and Gettering Problems in the Detector Housing

An Irtran-4 seal using Germanium could not maintain the minimal system vacuum required for the generation of acceptable data.

The vacuum requirement called for an internal pressure buildup not to exceed one micron per year.

The MEB traced the problems to:

- (a) Improper barium getter firing in vacuum, which produced a relatively inactive material.
- (b) Improper "gas generating;" sealing procedure used on the detector package.
- (c) Utilization of a glass gettering envelope with high surface concentrations of moisture.
- (d) Inadequate preliminary bake outs of the detector package.
- (e) Utilization of high outgassing polymers in the system.

MEB investigated and recommended far reaching design and material changes. It coordinated the efforts of, the detector envelope builder who corroborated the MEB observation, the high vacuum X-ray tube manufacturer who performed outgassing tests and the prime contractor. As a result of this collaborative effort, the following recommendations were acted upon.

- (a) The barium getter was fired in the presence of low-pressure argon-producing a porous, active getter surface with greater trapping potential for later evolving residuals of oxygen, carbon dioxide, nitrogen, and water vapor.
- (b) The original glass getter bulb was replaced with a Kovar housing, thus eliminating surface contaminant outgassing problems.
- (c) A major change in the "seal-off" procedure from a hot-tip to a cold-tip type eliminated combustion gas-getter interaction. Silver tubing

substituting for the glass seal-off tube was simply crimped, snipped and then dipped in solder for sealing.

- (d) A prebake was adopted (as incorporated in Review Team Recommendations) which involved system bakeout at 90° C for 72 hours, performance of necessary calibration and tests, Krypton back-filling and finally system venting just prior to launch.
- (e) Replacement of unsuitable polymers with low outgassing epoxies was accomplished.

The MEB's major contribution was in recognizing all the outgassing problems, the need for bake-out, the benefits of a cold tip-off, replacement of the glass getter bulb with metal, improved getter firing technique, and finally, incorporating these changes prior to the final testing program. The sum of all of these detail improvements is what was finally needed to meet the one micron per year maximum pressure increase requirement. The detector was an unqualified success.

VTPR - Potential Center Frequency Shift of the Germanium Filter

Maintenance of band width and center frequency of coated germanium filters is critical to proper functioning of the VTPR detector. The MEB was requested to initiate an investigation of VTPR infrared window materials. Of primary concern was the determination of UV, electron/proton radiation environment and contaminating film effects on the instrument. Also determined was that a center-frequency transmission shift would occur as a function of temperature. Since a constant center frequency is very critical for obtaining useful data from the experiment, the information made it possible to institute more stringent temperature control specifications for the detector, prior to flight application.

ITOS-D VTPR - Experiment Calibration Problem

A series of VTPR transmission filters are critical to the experiment's calibration of the whole optical network (ETALON). Two suppliers provided values for the band width cutoff and center frequency which were in complete disagreement. At the request of the Project, the MEB undertook to adjudicate this discrepancy. A procedure was adapted, which permitted attaining maximum sensitivity and resolution of the PE 621 spectrophotometer and allowing the measurements to be reproduced several times to insure their validity. To achieve this accuracy, CO₂ was employed as a standard. Optimum parameters, for measuring the filters so that their center frequencies could be rigorously established, and any possible optical aberrations detected, were determined. By introducing these refinements (sensitivity factor of 100) which pushed the PE spectrophotometer

to its maximum capability, the experimenter was provided with a precise calibration in the required 12.5 to 16.5 micron region, thus resolving the discrepancy. The experiment was properly calibrated and the required temperature and altitude resolution was obtained and confirmed by Mr. John Brown of the Earth Sensors Branch.

ITOS-D - Bearing Surface Study

An extensive surface measurement study on bearings for the VTPR experiment was designed and supervised. A correlation between surface roughness and optical appearance was established and a surface finish standard was incorporated in the vendor Specification for the bearings.

ITOS-D Very High Resolution Radiometer (VHRR)

Development of Diffuse Black Coating—The sophistication of this radiation detector, relative to its required sensitivity in the visible channel, made it mandatory to reduce optical noise (scattered light) from surrounding surfaces to a minimum, especially at low grazing angles of incidence when most surfaces became specular.

To reduce such reflections into the instrument, the vendor proposed using 3 M's 401 Black Velvet Epoxy Paint on the thermal insulation of the earth-facing panel. However, due both to its tendency to flake off as the insulation is flexed, and its marginal outgassing properties, the MEB recommended using a black flexible urethane paint Chemglaze Z306, as a substitute. Furthermore, the MEB proceeded to develop an even more superior retroreflective paint by incorporating microspheres (hollow glass balloons) in the Chemglaze Z306. The combination of a low outgassing, mar resistant paint coupled with the good optical properties of glass balloons yielded an excellent diffuse coating, but because time constraints precluded requalification, this advanced formulation was not employed at that time. However, in view of this coating's low outgassing and general applicability for low reflectance areas, it is currently being used on the interior of the optical train of the SAS-C sun sensor and on the 26-inch diameter sun shade of the IUE satellite.

Post Launch Sensitivity Loss in VHRR (ITOS-D/NOAA-2)

The Project Office determined that the observed loss in detector sensitivity could not be ascribed to an electronic malfunction and requested an investigation to determine whether molecular contamination could have been responsible. Exhaustive tests were conducted with materials near the detector. It was concluded that silicones could have been the contaminant condensing on the VHRR filter, especially since it was possible that a faulty nutation damper or even the

solar panels might have provided the required source. Subsequent T/V chamber tests, incorporating a quartz crystal microbalance (QCM) as recommended by the MEB, provided further credence to the S/C contamination theory and prompted the Project to inaugurate a major filter design modification. The MEB's contribution to resolving this problem consisted of suggesting the use of QCM during T/V tests, pointing out probable contamination causes, specifying solar panel bakeout, and performing detailed analysis of construction materials. In addition, an in-depth evaluation was carried out on structural polymers with low thermal conductivity capable of achieving maximum thermal isolation of the detector, yet still exhibiting, low outgassing profile, ease of machining, and compatibility with other S/C materials. As a result of this latter effort, polycarbonate was recommended as the best standoff material to mechanically support the filters on ITOS-H, I, and J. This material will be used.

Potential Bremsstrahlung Problem

NOAA requested the MEB to evaluate the possible effects of Bremsstrahlung radiation (noise generated by secondary emissions, principally X-rays, produced by electrons and protons colliding with materials) in orbit on the VTPR pyroelectric detector. The MEB designed and supervised a radiation test program to determine the detector signal to noise (S/N) ratio during irradiation with orbital level electrons. The data generated, along with a calculation of the shielding provided by the spacecraft, carried out in cooperation with vendor engineers, determined what, if any, additional shielding would be required for the detector. These results indicated, that no significant noise would be obtained at peak orbital electron fluxes and thus not only established that additional shielding was not required for the instrument, but enabled the experimenter to accurately assess funding and time impact on the program as a whole. In addition, it is significant that during the calculations which led to the testing, the MEB recognized that the instrument's performance could be marginal over the South Atlantic "anomaly" based on data which was available at the time. Therefore, a request of Mr. E. Stassinopoulos was initiated for dose rate estimates at any point during a given orbit. Up to this time, only integral type data was available. These requirements, therefore, helped detail the electronic structure of the Van Allen Belts in the South Atlantic.

ITOS-E

Momentum Wheel Assembly

MEB staff visited the six inch "Momentum Wheel Assembly" manufacturer after high current operation was observed during the ITOS-E T/V test. MEB recommended an improved surface finish, less than one micro-inch AA for the bearing

race, a configured retainer, new lubricant (Krytox 140AB), and the replacement of a bronze retainer with Synthane LBB. Life test data, presently very favorable, will be completed in several months. The system will be used, if still successful at that time.

Vendor-Thermal Vacuum Test Chamber-Upgrading

MEB monitored the vendor's thermal vacuum tests involving ITOS-E array panels, over a six month period and reported on the gross contamination of their chamber. The vendor was convinced and has resolved to take all necessary steps to upgrade his system by substituting "non outgassing" components throughout all of the chamber's internal wiring. In addition, a quartz crystal microbalance will also be used inside the chamber for determining when outgassing is effectively completed.

ITOS-F

Thermal Louvers

Thermal louvers on ITOS-F blistered during thermal vacuum tests at the vendors. MEB examination and study indicated that blistering was due to overheating several layers of paint under the aluminum sheet, the paint had not been stripped before laminating. Panels were subsequently cleaned of all paint and relaminated with aluminum foil. No subsequent blistering occurred. The thermal louvers performed successfully in orbit.

TIROS-N

Orbit Adjust System (OAS)

MEB investigated the possible adverse effects of hydrazine thrusters on materials in space. The possibility of N_2H_4 degrading As_2S_3 antireflection coatings was demonstrated but this was the only material found to be affected. However, gaseous hydrazine was shown to have no effect.

VHRR

MEB investigated the corrosion problem involving the magnesium housing of the cooler. Tests were conducted on candidate barrier coatings and a

system consisting of sprayed EPON 828/Versamid-140 on DOW 17 was selected. The coating adhered well and passed a standard salt spray test without evidence of corrosion. The coating protected magnesium housing flew on ITOS-F and will fly on ITOS-G, H, I, J.

TIROS

Vidicon Face Plate Problem

MEB provided microprobe analysis in support of a Vidicon face plate study. In this task the degree of homogeneity of Selenium (Se) coating on the surface of a tin coated glass Vidicon face plate was determined. The results of this investigation were extremely useful in describing the distribution of Se statistically and was instrumental in achieving consistent quality of face plate production with improved Vidicon tube reliability.

SMS

Investigation of Photomultiplier Drift and Instabilities of the VISSR Flight Tubes

Instability was found to occur when high intensity light projected on flight PM tubes caused a 10-15% loss in gain with subsequent slow recovery. Because radiometer accuracy of better than 2% was required for the visible bands of VISSR and ERTS-MSSC, the Earth Sensors Branch requested an investigation of radiation sensitive variation on flight qualified VISSR PM tubes under simulated operating conditions. The Subcontractor and vendor could not provide this information. The MEB was then requested to conduct an extensive parametric study of radiant sensitivity on representative flight qualified tubes.

A parametric model was developed which allowed the quantitative prediction of tube sensitivity variation under all operational conditions of practical interest, thus defining operational modes on the spacecraft.

Findings are pertinent to all PM tube applications where radiometer accuracy has to be maintained without frequent calibration. ERTS-MSSC operation was given a valuable assist because potential problems were identified and avoided by suitable operational techniques.

HEAO

HECRE - Cesium Iodide Spectrometer

The water sensitive cesium iodide crystal, heart of this system was a very special problem. The MEB developed techniques to encapsulate the crystal yet provide silicone oil within the encapsulant, as a vibration damper and light transfer medium. In addition, experiments showed that cesium iodide mosaics could replace expensive one piece, crystals (40 cm x 40 cm x 2 cm) with resultant cost savings. Optical parameters were established for determining quantitative measurement, of scintillation response, quality, and efficiency. The entire CsI module was qualified for flight use.

Spark Chamber

The spark chamber's especially fabricated BeCu grid wires became contaminated and unuseable, due to gaseous exposure during preliminary trial balloon flights. The need for a \$60 K replacement was eliminated by the MEB's specially developed chemical refurbishing technique which permitted reusing the spark chambers. The unit subsequently flew successfully in another balloon flight.

IMP-I

IMP-I, Ion Guard

The Ion Guard silicone rubber sleeve on the antennae turned brown during UV exposure in laboratory tests, leading to excessive temperatures and degraded electricals. The MEB formulated a UV resistant white silicone coating for the sleeve. The unit was flown successfully.

IMP-I, RF Shielding

The following is a table of critical experiment hardware whose connectors were RF shielded using the MEB in-house development. Some units were shielded directly on the spacecraft in situ when it was deemed inadvisable to remove the harness from location.

Although IMP-I was an in-house project, the same procedures were instructed to the vendor, for RF shielding cable connector assemblies on the IMP-H and J spacecraft. These spacecraft are presently in orbit and no problems have been encountered. The new ISEE satellites, Interplanetary Sun-Earth Explorers, will be similarly treated.

Experiment	No. of Connectors Shielded	No. of Connectors Shielded in Situ
GSFC Cosmic Ray	10	
Iowa Low-Energy Particles	2	
CAL-Medium Energy Particles	2	
GSFC-Plasma	1	
Iowa-AC Elect & Magnetic Fields	5	1
GSFC-Magnetic Fields	2	
Total	22	1
Instrumentation		
Telemetry & Command	1	
Electrical	3	2
Control	6	
Total	10	2

IMP-H

University of Chicago Cosmic Ray Experiment

This experiment developed open circuit failures in its solid state particle detector interconnects. The MEB diagnosed the problem as an overstressed conductive paint strip, redesigned the interconnect structure body. The redesigned experiment flew successfully on IMP-H.

IMP-H Particle Detectors - Surface Barrier Detectors

Two vendors, were using health hazardous methanol in making detectors, assuming that this was the only solvent which would not degrade the detector's required sensitivity. A test program set up by the MEB with one vendor's laboratory director demonstrated that leakage current and detector noise were

unchanged after using safe isopropyl alcohol. Project management, experimenter, and vendors were convinced. Isopropyl alcohol was subsequently used in the process. The Particle Detector flew successfully.

IMP-J

Magnetometer Boom

The MEB determined through laboratory analysis that a failed flipper mechanism resulted from excessive fatigue; recommended design and material changes, which were successful.

Electric Field Measurement Experiment

The MEB examined and evaluated all aspects of the gear, bearing, and lubricant system. Recommended Krytox 240 AC, a new lubricant which enabled the system to function successfully in orbit.

AE

Cylindrical Electrostatic Probe

This probe, heart of the electron density experiment, is a 16" hollow nickel tube closed off at the sensing end. A four-inch length of the exposed probe is subsequently deposited with 0.0075" of tungsten. It is required for maximum efficiency, that the tungsten be of uniform thickness, highly polished, with long axis of the crystal grain extending radially from the nickel tube. Such properties insure both maximum work function and low photoemission characteristics, respectively, essential requirements for probe sensitivity. An MEB metallurgical examination of the tube's cross section after early vendor attempts at deposition, revealed that the tungsten coating had been laid down eccentrically. Improved concentric coatings were made by inducing the manufacturer to rotate the nickel tube during tungsten deposition. Furthermore, it was established that although later coatings were concentric, they still contained many surface irregularities which gave the tungsten a greyish cast, and increased the undesirable photoemission level of the probe. The MEB developed a slow, temperature sensitive, electrolytic deplating technique using the tungsten coated probe tube as an anode. This technique resulted in a highly polished tungsten surface, having a minimal photoemission level. The experiment is performing successfully in space.

The possibility of using rhenium instead of tungsten is being explored by the MEB because of rhenium's higher work function, with corresponding lower photo

emission possibilities and greater sensitivity. Such a collector probe may fly on future spacecraft.

TAL (Temperature Alarm System)

A thermal expansion problem between tungsten grid wires and Vespel SP-1, polyimide support pins, at 400°C, caused distortion of the wires. Recommendation of a lower expansion material, SP-5, a filled polyimide, and a more realistic test temperature (200°C) resolved the problem.

MIMS (Magnetic Ion Mass Spectrometer) Experiment

A series of seven grids (gold plated tungsten 1 mil diameter mesh) contained in the sensor portion of the MIMS experiment, were anticipated to experience a temperature increase caused by ram-heating as the spacecraft approached perigee. Predicted temperature for several of the grids was above 400°C for a period of several minutes and questions arose as to whether the gold plating would flake off or diffuse into the tungsten. The MEB thermal cycling tests on gold plated tungsten mesh, submitted by the experimenter, showed that the gold plating remained visually unchanged. Metallurgical examination indicated that neither flaking nor diffusion occurred. The MIMS is operational in space.

NATE (Neutral Atmosphere Temperature Experiment)

The NATE stepper motor/gearhead was submitted to the MEB by the Michigan Experimenter following its failure (motor stall) during thermal vacuum testing at 50°C. Intermittent jitter and spasmodic tripping had been noted at other temperatures. The motor gearhead was opened up by the MEB and all surfaces carefully examined. The lubricant was bonded solid film MoS₂, molybdenum disulphide, which had been subsequently burnished, or burned in, by 50 hours of motor operation. Excessive MoS₂ residues, created by the burnishing, caused jamming of the close tolerance mechanism. In addition, the motor preload feature was twice the amount required.

The unit was carefully cleaned with high pressure air, unlubricated areas were resurfaced and one of the two preloading shims removed for smoother operation. The motor was finally run in with periodic cleaning and returned to the experimenter in excellent operating condition. A second unit similarly prepared for flight use is performing successfully on AE now in orbit. In view of this recurrent problem, Krytox grease 240 AB, a new lubricant, is being recommended for future units. This should provide a better motor, a more effective lubrication system, no residue problems, and could result in a reduced overall cost.

Hydrazine Tank Diaphragm Failure

Subject diaphragm developed cracks during system vibration qualification. The MEB metallurgical examination demonstrated definite fatigue failure arising from local high stress concentrations in low stiffness areas. This was the direct result of greater than normal plastic distortion and geometry changes as the diaphragm reversed itself during vibration. The MEB recommended that no tanks be flown with reversed diaphragms. This was implemented. No tank problems have occurred to date.

SAS-B

Tape Recorder Drive Belt Failure

The MEB investigated the Mylar drive belt rupture, a problem which results in mission failure, since spacecraft data can neither be collected nor disseminated under such circumstances. Examination with the "Scanning Electron Microscope" revealed that the stretched, notch-sensitive drive belt was particularly sensitive to stress rupture penetration caused by fine metal particles, debris, picked up as the belt moved through the recorder. Recommendations were made for intensive cleaning of the housing and for minimizing pickup through use of an antistatic spray. Additionally, design considerations were recommended for minimizing particulate contamination of the recorder. SAS-B was placed in a nominal 440 kilometer perigee, 630 kilometer apogee, equatorial, 100-minute orbit in November 1972. The two specially cleaned recorders on board are working well to date, May 1974, as an engineering life cycle test; each operating on every other orbit. Successful SAS-B mission life was established at six months. These recorders have individually exceeded eight months of continual operation. SAS-C recorders will be similarly handled. However, special precautions will be taken to lessen static buildup with a brush bleedoff.

HELIOS-A/B

Solar Cell Interconnect Coating

Dr. Gurney's Iowa experiment, No. 5, required that all exposed solar array wiring including cell interconnects, be covered with insulation having low conductance values at 150°C, i.e., a maximum of 1×10^{-11} mhos cm^2 . This was necessary to repress electrical noise resulting from space plasma coupling to exposed wires. Silicone DC6-1109, a flexible, low outgassing, high resistivity insulation, when cured, was tested and selected. The insulating coating adhered well and protected the silver plated interconnect from tarnishing. Successful

procedures were established for hypodermically coating the interconnects through the 0.015" thermal expansion gap between solar cells. These techniques were submitted to the vendor, builder of the Helios array and are presently being implemented. The experiment should have minimal noise background.

Antenna Reflector Wires

The MEB investigated and carried out studies on the absorption and emissivity of silver plated platinum materials overcoated with vacuum deposited aluminum oxide. This composite has potential for use on the antenna reflector. Exposed temperature of the wires is anticipated at about 450°-550°C. Actual studies were made at 350°C-475°C. Recommended reconsideration of a solid platinum or platinum/rhenium wire despite its initial higher α .

Propellant Motor Contamination

Possible contamination of the Helios Zodiacal photometer optics from the TE 364/4 solid propellant motor was investigated by the MEB and it was concluded that contamination from the exhaust products, per se, was considered unlikely. However, contamination of the optics by the copious amounts of decomposition products from the motor's 15 pounds of carbon black filled rubber insulation-liner and other heat sensitive materials was considered very likely. Especially, since the motor and spacecraft remained attached for about three minutes after burnout. Recommendation to preclude or reduce this potential contamination by sealing apertures or back pressurizing with nitrogen was submitted.

IUE

Sun Baffle

The MEB has developed a non-reflective, low outgassing black coating for minimizing any stray light impacting on the IUE optics. Basically, it is similar to the Z-306 applied to the Copernicus baffle. However, it also contains glass balloons of 74-63 μ diameter for its non-reflective properties. The absolute specular and reflectance resulting from a 15° angle of incidence is the lowest to date and 1/3 that of 3M's 401 Velvet Black which has been the accepted standard for many years. The MEB is providing paint, additives, and procedure to IUE personnel for application at the vendors in Europe.

ANS

HXX - Hard X-Ray Experiment

The MEB assisted in solving the problem of obtaining a successful proportional counter for the hard X-ray experiment (HXX) after contractors were plagued with internal contamination and leaking 0.001" thick beryllium windows for a year. With costs escalating, the MEB reviewed the problems and recommended:

- (1) Cleaning with alcohol and demineralized water in a prescribed sequence,
- (2) Bake out of the counter at 100°C with the original gas charge, followed by flush, and refill; and finally,
- (3) Using 2 mil instead of 1 mil beryllium windows.

Due to continued Xenon gas idiosyncracies, however, a new argon, carbon dioxide mixture was selected by project. Successful units have been obtained by project from the vendor.

Materials Procedure and Facility Review

At the request of the Netherlands Space Consortium, one of the MEB Staff visited several major fabrication and laboratory sites in Holland. Many innovations were made, anti-contamination procedures were instituted, seemingly innocuous pitfalls were forewarned against, a review of generally acceptable materials was presented, and MEB's future assistance and services were extended for any problems they might encounter. A very appreciative letter from the "Industrial Consortium Astronomische Nederlandse Satellite" indicating their gratitude for making this expertise available has since been received. This is but one other instance of many, wherein the MEB directly has helped cement technological relations with other nations involved in space research.

SOUNDING ROCKETS

Tomahawk - Heat Shroud Evaluation

To determine the suitability of employing a 0.0005" thick aluminized Kapton as a heat shroud to protect delicate instruments in a future series of Tomahawk vehicles, the MEB designed an experiment utilizing the High Strain Rate Tester which is capable of providing resistance and radiation heating. From past flight experience, the temperature extremes were indicated as 700°F on the inside surface of the nose cone, while the maximum temperature acceptable within the

instrument area was not to exceed about 140°F for a period of approximately 400 seconds. The specific recording instrumentation and novel test setup revealed that a single layer of 0.0005" film would provide the required thermal protection at temperature levels reaching 1200/1400°F, when the film was applied inside the nose cone.

Nondestructive Testing (NDT)

A most important and cost effective support function continuously being carried out by the MEB, involves determining the structural integrity and acceptability of recoverable sounding rocket nose cones, instrument capsules, structural extensions and the like using various non-destructive methods (dye penetrant radiography, etc.). Meticulous examination and analysis has been performed on literally hundreds of components, most of which had been acceptable for re-use on many occasions.

Sounding Rockets - Black Brant Vehicle

Cooperating with the Sounding Rocket Division and a "Brant" subcontractor, the MEB was successful in developing a black ablative coating intended for all future Black Brant Vehicles having SPARCS as part of the mission operation. This composite ablative was designed to replace the present ineffective ablative/coating system required on the vehicle's aft can and fin assembly. It eliminates the need for both preparation and overcoating of the previous ablative surface and, most important, it removes the undesirable reflections that can possibly emanate from the aft can assembly. These spurious reflections from can and fin have been interfering with SPARCS attitude control guidance of the vehicle. This guidance is wholly dependent on SPARCS being able to lock onto the sun without being influenced by other disruptive surface reflections.

In addition, a new flat black high temperature paint was successfully developed and recently applied to the motor casing of two Black Brants.

Since this ablative coating process is compatible with the current production methods employed by the prime vendor, it will be a time and cost effective operation.

DELTA

Hydrazine Incompatibility with DELTA 410 and 301 Stainless Tankage

An important vendor had reported tests indicating hydrazine incompatibility with tankage made of 410 and 301 stainless steel. The 410 was being used by GSFC as stress bearing structural tankage in the second stage Delta. Pressure

vessels of the 301 were being used on AE, SMS, and the RAE satellites. The MEB was called in to assist the Delta Review Committee in evaluating the significance of the vendor's report. Test programs were immediately set up to evaluate highly stressed 410 stainless with varying purity hydrazine over a thirty day period. No failures resulted, indicating compatibility at the high stress levels. Concurrently, two additional programs were set up, one evaluating 301 stainless pressure vessels with varying hydrazine impurities and one evaluating hydrazine, propellant grade, against 301 stainless in a fracture mechanics approach. Again, no failures occurred. The Delta Review Committee followed the MEB recommendation that there would be no problems under flight conditions normally encountered. All involved spacecraft and launch vehicles subsequently flew successfully. The vendor later reported that their initial incompatibility results had originated with impure hydrazine.

Cracking of Motor Mounts

The Delta Review Committee requested the MEB to investigate the cracking problem involving several welded aluminum motor mounts on a vehicle scheduled to launch ERTS-A.

Metallographic analysis indicated that all 6061 aluminum alloy motor mount assemblies were in the correct heat-treated condition and that the majority of hairline cracks noted were superficial, either weld-related or weld aggravated and not due to structural loading. All of the cracks were ground out and a very conservative stress analysis confirmed that safety margins had not been exceeded. The Design Review Team recommended that the vehicle fly. ERTS-A was launched successfully.

BEARING AND LUBRICATION FACILITY

Historically, a disproportionate number of problems brought to the MEB's attention are concerned with ball bearing, gear, and other lubricated systems.

There are many reasons for the relatively high incidence of lubrication problems that plagued GSFC spacecraft systems. These include inadequate design, improperly specified lubricant, broadly varied service environments, long time storage, contamination, etc. However, a significant share of the reason for lubrication problems depends upon the inadequacies of the bearing, gear, motor, etc., manufacturer, especially in the following areas:

- (1) Current procurement specifications are inadequate to meet surface finish requirements vital to performance and long life reliability with marginally lubricated components.

- (2) Vendors have problems in controlling proper material identification, quantity of lubricant specified, and method of application.
- (3) Vendors are not set up to clean flight bearings, reservoirs, etc., with the appropriate skill and solvents necessary to achieve the required level of confidence for space use.
- (4) Vendor inspection procedures, while adequate for most terrestrial needs, do not measure up to the quality assurance requirements demanded of lubricated flight hardware.
- (5) Improper handling procedures crop up periodically after components have been lubricated. In part, this could be attributed to a lack of appreciation of the criticality of their functions in a spacecraft mechanism or instrument, that must perform successfully unattended for a long period of time.

Recognizing the importance of bearing lubrication, and especially as it concerns careful examination of high magnification and thorough cleaning of porous components, such as cages and reservoirs, the MEB undertook the responsibility to provide lubrication support for the benefit of the Center's flight projects. A unique facility was established capable of providing complete processing (i.e., inspection, cleaning, lubrication, etc.) of vendor bearings, including some testing. This clean room facility is used for the evaluation of bearings, gears, cams, and electrical brush mechanisms requiring some form of solid or liquid lubrication. Probably one of the most important features of this service is the timely response to project requests and their confidence in the inspection procedures and processing carried out by the MEB. The facility processed 157 flight bearings for the projects in 1973 and it is anticipated that this quantity will be exceeded in 1974. The following is a partial listing of projects which have benefited from this specialized bearing preparation procedure.

ATS-F/VHRR	ERTS-A&B/SAD
Nimbus-F/HIRS	Nimbus-E/SCMR
IUE/Focus Drive	Nimbus-E/THIR
ITOS/SR	RAE-B
Nimbus-E/ESMR	Tiros/AVHRR
Nimbus-F/LRIR	ERTS-A/MSS
Nimbus E&F/SAD	

APPENDIXES

**MATERIALS ENGINEERING BRANCH
STATISTICS**

MATERIALS ENGINEERING BRANCH STATISTICS

As previously indicated, the main thrust of the MEB's personnel and resources are dedicated to timely, effective, and efficient project support. Increased efficiency has been demonstrated by the mounting volume of support data handled, as our staff manpower decreased over the last 3 years. Representative graphs for the period December 1970 - December 1973 illustrate: Figure 1, total volume response to overall analytical requests; with breakdown into analyses types; Figure 2, available manpower vs total analyses; Figure 3, technical memo volume related to overall spacecraft problems and; Figures 4 & 5, frequency of response to a specific spacecraft's problems. Most significant is the fact, that a 45% increase in analyses output within 3 years, has been accompanied by a 22% decrease in available support personnel. Some of the improvement has resulted from increased instrument automation, some from our newly instituted memo bank data retrieval system, some from the development of more knowledgeable and experienced staff, and some unfortunately, to forced withdrawal from formal ART/SRT programs.

The increase in demand for MEB support rises:

- (1) From MEB expertise in how contamination occurs, what its effects are, where to find it and what to do about or control it. "Zero contamination defects" is the password to effective flight hardware instrumentation and realistic data accumulation. Sophisticated radiometers are notorious for failing due to Angstrom thicknesses of deposited contaminants.
- (2) From MEB expertise in the perennial problems of lubrication for moving parts, essential to hardware operation.
- (3) From MEB expertise in probing and understanding the physical and chemical properties of metals, ceramics, and polymers, how these materials interact in spacecraft, and with the space environment.
- (4) From our dissemination of technical literature dealing with safe, practical "how to do it" concepts related to space hardware.

The demand for MEB support has increased as each "new start" has instituted more vigorous material review provisions as part of its overall reliability enhancement concept. This has been promoted by the MEB liaison attached to the "new start." Recently, at the MEB's request, however, and after legal and top management approval, the Procurement Division has been including a "Materials Evaluation" schedule in the initial RFP design review phase of a new start. This is binding upon the tentative vendor, project manager, technical officer, and other cognizant staff. The driving force behind this "early materials evaluation"

program is the need to have the vendor settle on his material requirement in the design review phase so that production can later proceed with minimal interruption and at no increase in costs. There have been occasions, where MEB's requests for an obviously improved material change during production, have elicited demands by the vendor for additional dollars because of "change in original scope of contract." We have then, a built-in provision for increasing the MEB material evaluation services early in a "new start's" lifetime, thereby potentially limiting later failures of a gross and costly nature.

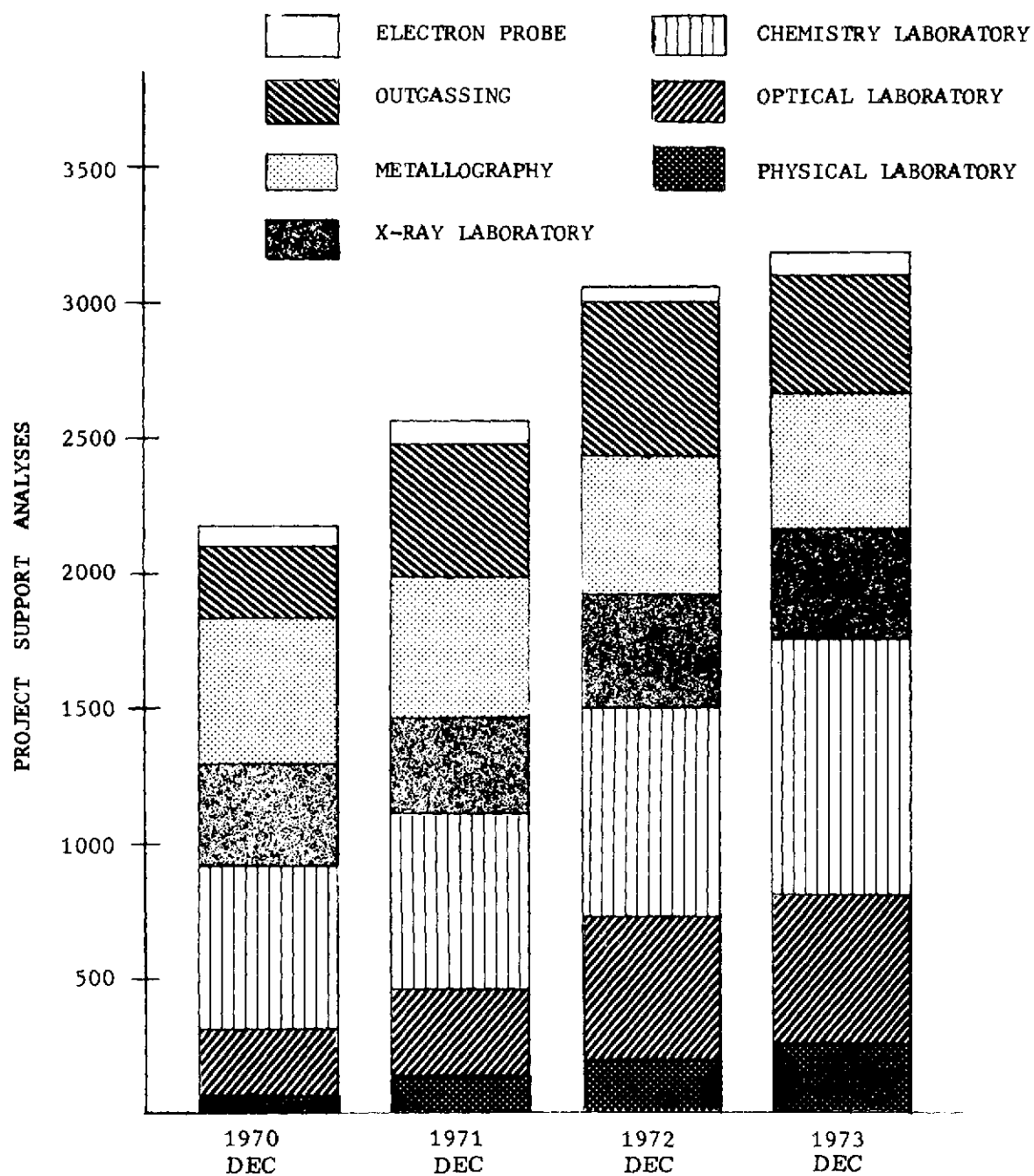


Figure 1. Total Volume Response to Overall Analytical Requests With Breakdown Into Analyses Types

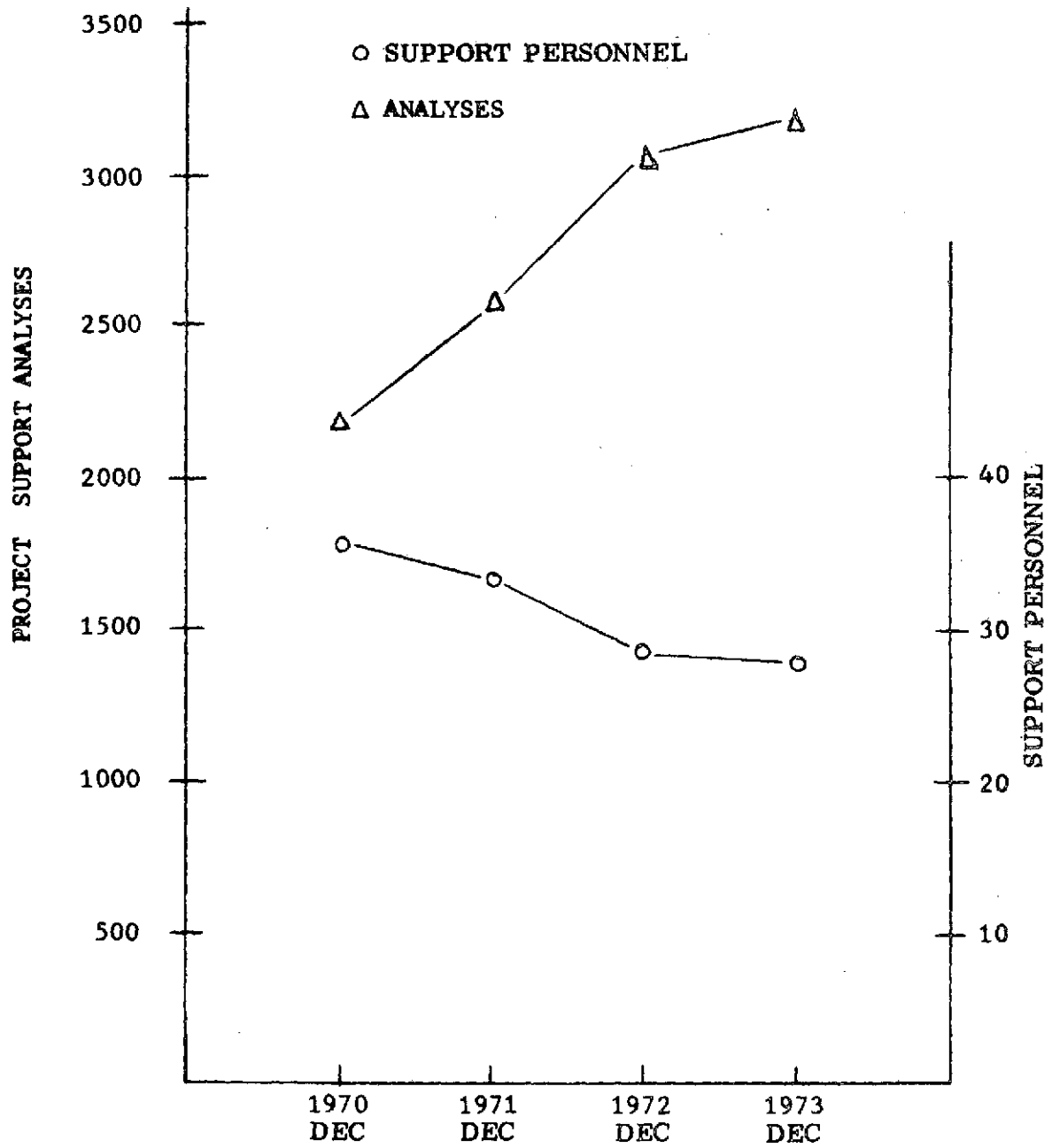


Figure 2. Available Manpower vs Total Analyses Completed

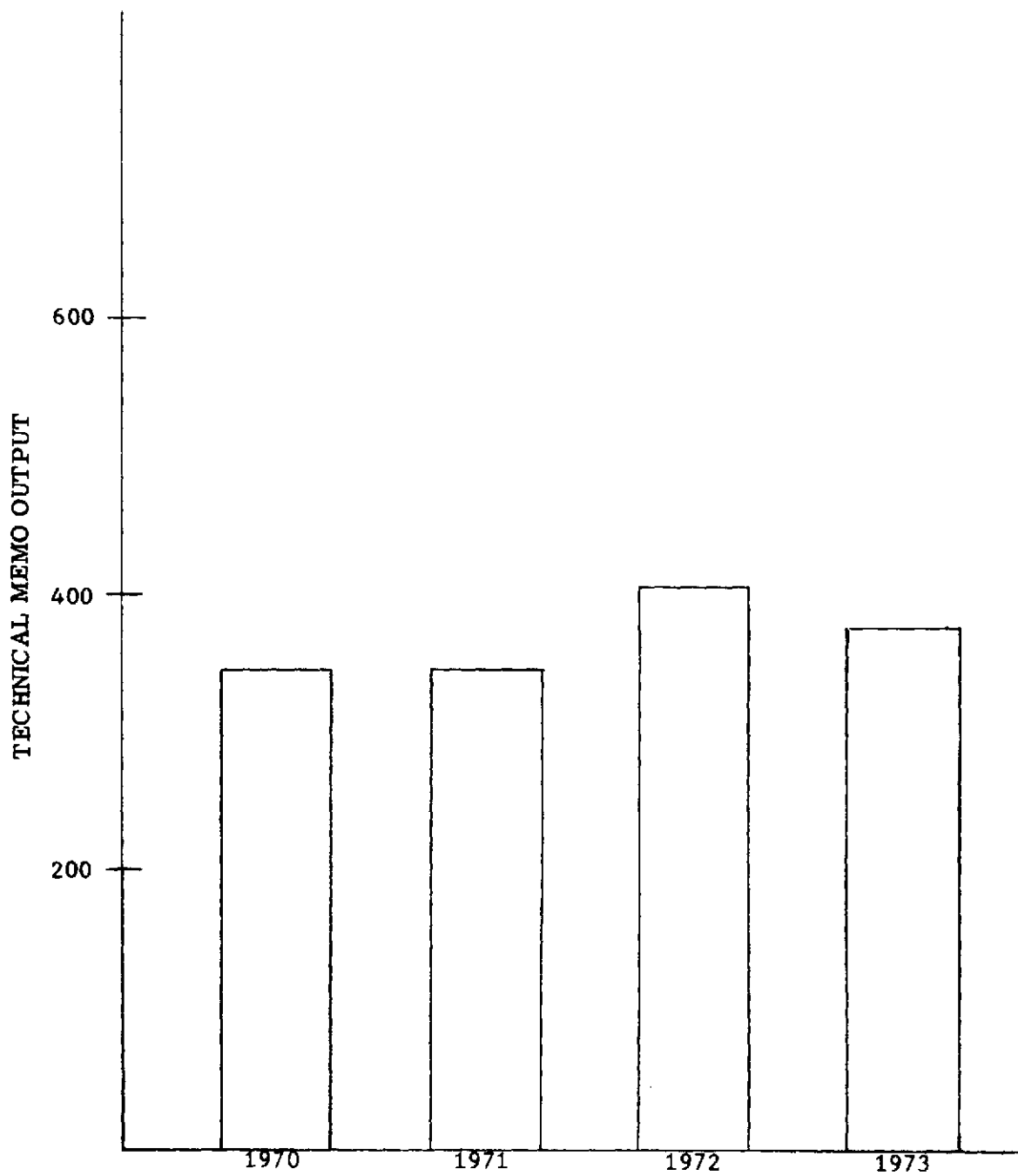


Figure 3. Technical Memo Volume Related to Overall Spacecraft Problems

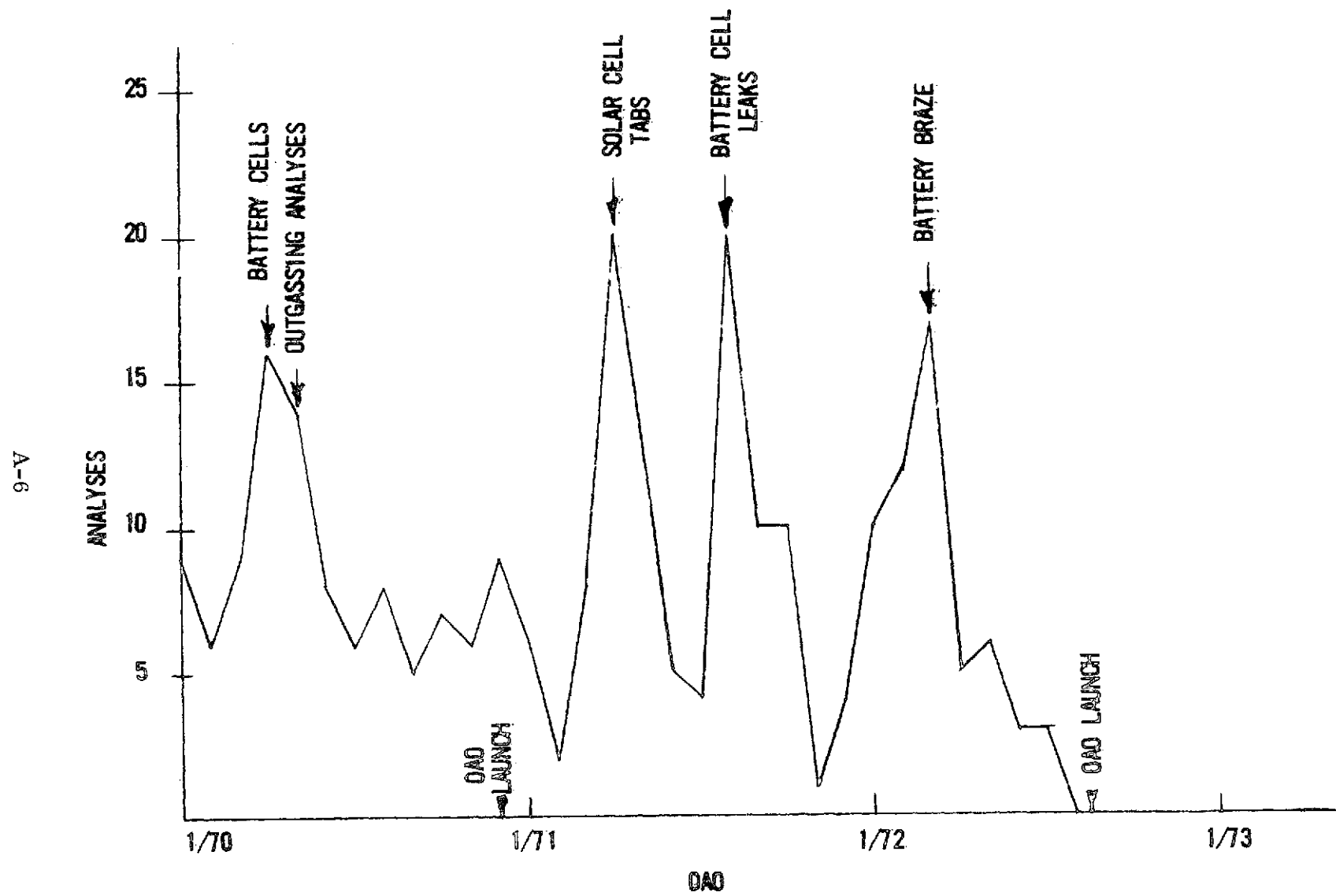


Figure 4. Frequency of Response to OAO Spacecraft Problems

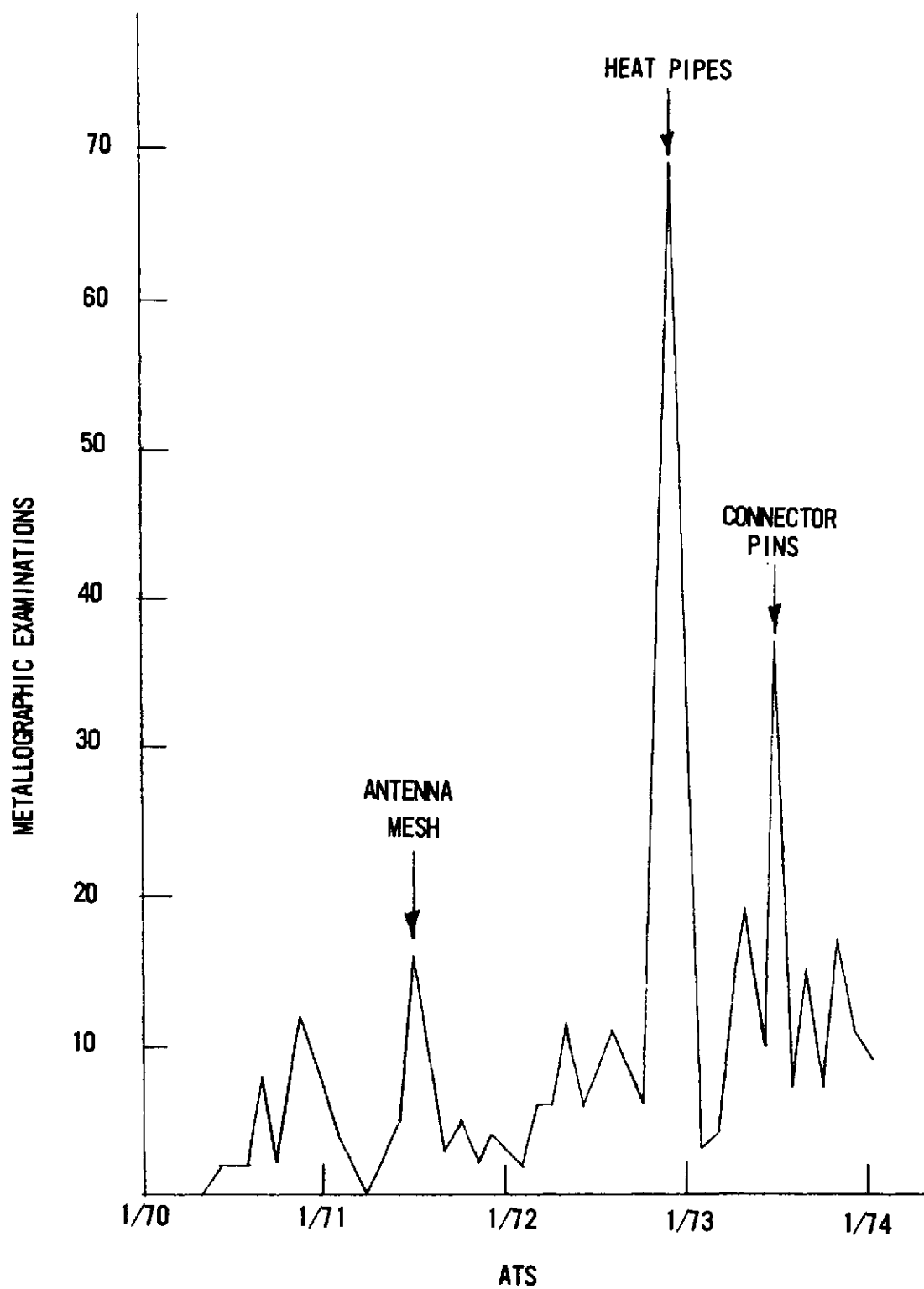


Figure 5. Frequency of Response to ATS Spacecraft Problems

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PUBLICATIONS**

MATERIALS ENGINEERING BRANCH PUBLICATIONS

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MEB STAFF
ASSOCIATED DISCIPLINES
AND
MAJOR SATELLITE SUPPORT EFFORT

A-17Q

The substance of this document has evolved primarily from the sustained and dedicated effort of the total MEB staff. Respective discipline areas and space-craft liaison associations are indicated below:

<u>Name</u>	<u>Discipline</u>	<u>S/C or Experiment Liaison</u>
C. Staugaitis	Metallurgical Engineer	AEROS, MJS, Space-lab Shuttle
E. Ackerman	Administrative Secretary	
Dr. A. Eubanks	Materials Engineer	OSO, TIROS, CTS, ASP
Dr. J. Park	Materials Engineer	OAO, IUE
A. Babecki	Metallurgist	NIMBUS-LST
A. Fisher	Polymeric Materials Development and Application	HELIOS
T. Heslin	Ceramic Technologist, Physicist	TIROS-N, ITOS
R. Hunkeler	Materials Engineering, Ceramic Development & Testing Technician	Project Support
L. Kobren	Materials Engineer	OSO-SMM
E. Mielke	Materials Engineer	ERTS/RBV, ATS A-C, AE
E. Sanford	Materials Engineering, System Design and Testing Technician	Project Support
J. Tarpley	Solid State Devices, Thin Film Technology	IMP-H, I, J, HEAO, ISEE
W. Viehmann	Solid State Physicist, Opto/Electronics	ERTS/MSS, TIROS-N/AVHRR, HEAO/HECRE
W. Campbell	Physical Science Technician	Project Support
C. Clatterbuck	Polymers Development and Applications Technician	Project Support
J. Colony	Mass Spectral Analyst	Project Support

<u>Name</u>	<u>Discipline</u>	<u>S/C or Experiment Liaison</u>
F. Gross	Analyst and Polymeric Materials Evaluation	ANS
R. Marriott	Materials Engineer	SS, SMS/VISSR, UK-5
P. Sarmiento	Spectroscopist	Project Support
Dr. B. Seidenberg	Polymeric Materials	SAS-A, IMP-KK'
R. Sheehy	Vacuum technology and deposition Mechanical Technician	Project Support
W. Grenier	Metallurgical Engineering Technician	Project Support
J. Grimsley	Metallurgist	ERTS/NIMBUS
C. Haehner	Materials Engineer, Lubrication Application	SAS-B, C
C. Johnson	Materials Engineer	ATS, Sounding Rocket, DELTA
J. Jellison	Physical Metallurgist	Project Support
C. Vest	Metallurgist	SMS, GOES, TDRSS
H. Bahiman	Structural Engineering and Materials Analyst	Project Support

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